

Jonathan Rhoads, MD 1907–2002

Jonathan E. Rhoads, one of the 20th century's great surgeons, died at age 94 on January 3, 2002. His active professional career spanned the last three-quarters of the century and was responsible for the development of total parenteral nutrition, one of the most important medical advances of that period. Dr. Rhoads served on the editorial

role in raising their 6 children, for which she gave up a promising career in pediatrics.

During Dr. Rhoads' training in surgery at the Hospital of the University of Pennsylvania (1934–39), Eldridge Eliason was the department chairman. However, Dr. Rhoads' real mentor was I. S. Ravdin, who had a service totally inde-



Board of the *Annals of Surgery* for 55 years (1947–2002), from 1971–73 as Editor in Chief, and as a senior member of the Editorial Board until the time of his death.

Jonathan Rhoads was born on May 9, 1907. His father, Edward, was a physician who served his internship under D. Hayes Agnew and William Osler at the Hospital of the University of Pennsylvania, the nation's first University Hospital, which had opened only 11 years before in 1874.¹ Jonathan was a *Phi Beta Kappa* graduate of Haverford College. He was also a track star, excelling in the pole-vault, an event in which he was undefeated in intercollegiate competition. While in medical school at Johns Hopkins he met his classmate and future wife, Terry Folin, whose father Otto, a Professor of Biochemistry at Harvard, devised the well-known Folin-Wu method of measuring blood sugar. After graduation in 1932, Jonathan accepted an internship at the Hospital of the University of Pennsylvania and Terry accepted one at Yale. He credited her with the predominant

pendent of Eliason's that was staffed by his own residents. Less than a year after Rhoads finished his residency, Ravdin proclaimed the confidence he placed in his young trainee by selecting him as his personal surgeon when he developed acute cholecystitis. Dr. Alan O. Whipple (who was called from New York to consult) and Dr. Eliason were relegated to the role of assistants at the cholecystostomy, which was performed under spinal anesthesia. In response to Ravdin's kibitzing throughout the procedure, Whipple exclaimed "Rav, scrub up or shut up." Three years later during World War II, Ravdin went to Burma to command the 20th general hospital, leaving the 36-year-old Jonathan Rhoads in charge of his large service with only a skeleton crew of residents (including C. Everett Koop) to help him.

Rhoads later reviewed his productive early years at Penn, where he remained for his entire career²: "We began using Wangenstein Suction in 1933 or '34 and with William Osler Abbott participated in defining the use of the Miller-

Abbott tube. We operated on the first cases of Crohn's disease in 1933 and I believe the first islet cell adenoma of the pancreas about 1936. We attempted to transplant slices of it into the rectus muscle of a diabetic and to get the cells to grow in tissue culture. We got sulfanilamide in 1936, sulfadiazine by 1938, Vitamin K in 1938. I set up the Quick test for prothrombin in 1938 and personally ran all the prothrombins. About 1935, I did the first 4 peritoneal dialyses for uremia that were done in the Philadelphia area [probably the first anywhere]. We studied the effect of hypoproteinemia on wound healing and later its effect on hemorrhagic shock. I studied blood coagulation. . . . demonstrating that the prothrombin fell rapidly in the hepatectomized dog."

To review Rhoads' bibliography, from its first entry in 1935 to the most recent of his nearly 400 papers, written in 2001, is to chart the progress in the entire field of surgery over the last 7 decades.^{3,4} He wrote on virtually every subject, and many of his papers were seminal.⁵ His most important contributions were in the field of nutrition. Close behind was his broad interest in neoplasia. He wrote important papers on pancreatic, gastric, colon and breast cancer, and on a tumor marker for liver cancer. He was a pioneer in the study of coagulation and the use of vitamin K and Coumadin. During his early career he was a recognized expert on shock and burns. He was one of the first to use the sulfas for burns and peritonitis. Streptomycin became available just at the time he was diagnosed with advanced tuberculosis in 1946. Experience with damage to his own 8th nerve helped to define the toxicity of this drug, which also fortunately cured his disease.⁶ Other subjects of his reports were thyroid and parathyroid disease, parotid tumors, portal hypertension, intestinal obstruction, hernia, biliary surgery, wound healing, inflammatory bowel disease, and pediatric surgery.

On some topics he wrote only a single paper but this was often an important one, such as the one on peritoneal dialysis. It influenced Wilhelm Kolff, who is generally credited with the introduction of dialysis for renal disease.⁷ In 1949, he described a case of gastric hyperchlorhydria associated with multiple jejunal perforations and eventually treated successfully by total gastrectomy. Rhoads later learned this case report had been of considerable interest to Dr. Robert Zollinger, who later described the well-known "Zollinger-Ellison" syndrome.

In other instances, Rhoads carried out innovative procedures that were never reported in the literature. He wrote, "In 1945 we were called to see a patient with toxemia of pregnancy, who had developed both liver and renal failure with a mounting blood urea. I purchased some Visking tubing, a product made primarily as a substitute sausage casing but known to have excellent properties as a dialyzing membrane. . . . We did an arterial puncture and allowed the blood to course through the tubing, which was rolled around a wire test tube rack, immersed in a basin of [dialysis] solution. The blood was then collected and returned to the

patient by way of gravity into an arm vein. . . . This *in vivo* dialysis was highly successful in extracting urea from the patient. . . . and the blood urea nitrogen was reduced. Unfortunately, the patient had a hemorrhage that night (from which she did not die) but we had somewhat the feeling that logical as the approach may have been, it might have hastened her exit. Whether it did or not, it certainly did not save her and again we turned away from a procedure, which W.J. Kolff developed in Holland [at about the same time]. When Kolff visited the United States shortly after the war, he came to see me at the University of Pennsylvania. He mentioned our report on peritoneal dialysis and asked why we had not continued with it. The answer was simply that the patients, although they had been selected as possible acute renal shut down, proved to have chronic renal disease and did not improve. I believe that Kolff's experience was that he did 11 patients with only one survivor, but he did observe improvement of a temporary nature in some of the others."⁸

In 1956 Dr. Rhoads was appointed Provost of the University of Pennsylvania. As the University's top academic officer for the next 3 years he was able to maintain his large surgical practice only by operating all day on Saturdays and sometimes into the evening. In 1959, when Dr. Ravdin gave up the chair of surgery to become Vice President for Medical Affairs, Dr. Rhoads succeeded him as John Rhea Barton Professor and Chairman. The next 12 years were the busiest and most productive of his career. Besides his departmental administration and his busy clinical practice, he kept a number of other balls in the air. He was almost simultaneously Chairman of the Department of Surgery, President of the American College of Surgeons, President of the American Surgical Association, President of the American Cancer Society, Chairman of the Board of Managers of Haverford College, a member of the Residency Review Committee, the American Board of Surgery, the National Research Council and the Philadelphia School Board. In addition he was the editor of the *Annals of Surgery* and co-author of the most widely read standard surgical textbook.⁹

It was also during this time that Dr. Rhoads made his great research contribution – the development of total parenteral nutrition. This was the culmination of research in surgical nutrition he had begun in the 1930s and continued with the collaboration of generations of surgical residents until its fruition in 1966. The origin of Dr. Rhoads' focus on nutrition was the long-term interest of Dr. Ravdin in this topic. Together they had investigated the delayed gastric emptying seen after gastroenterostomy in malnourished patients.^{10,11} When hypoproteinemia was produced in dogs by plasmapheresis the suture lines of gastroenterostomies they performed were found to be edematous, which caused their stomachs to empty slowly. But if the dogs were given a high protein diet to correct the hypoproteinemia, gastric emptying was normalized. These findings were subsequently applied to patients in need of gastroenterostomies. Preopera-

tive transfusions of plasma significantly improved their postoperative course as compared with that of patients without preoperative protein repletion.

These studies of hypoproteinemia were the stimulus for identifying appropriate diets and methods of dietary delivery to malnourished patients. Because many such patients were unable to eat, Dr. Rhoads focused on finding methods to provide parenteral nutrition. In utilizing the intravenous route several limitations were encountered. One was the volume of fluid necessary to provide adequate caloric intake without precipitating pulmonary edema. But if the concentration of the glucose solution was increased to provide more calories in smaller volumes the infusate irritated and thrombosed peripheral veins. Dr. Rhoads' next approach was to diminish the concentration by increasing the volume (to as much as 5 liters daily) with the concomitant administration of diuretics. Although positive nitrogen balance was sometimes achieved by this method, success was inconsistent.¹²

The problem of delivering large volumes of hypertonic parenteral nutrients was then taken to the laboratory. The crucial experiment was performed by Dr. Rhoads' research fellow, Dr. Stanley Dudrick with the assistance of Dr. Harry Vars, the Department's biochemist, who devised the formula of nutrients and a method of continuous intravenous infusion in puppies.^{13,14} The controls received isocaloric diets by mouth while the experimental animals received only water by mouth and all of their nourishment parenterally via a catheter in the superior vena cava. The parenterally fed puppies grew normally and gained as much weight as the controls. This was the first demonstration that animals could actually survive, and grow, while receiving nutrients only by vein.

Because of the hyperosmolality of the parenteral solution, its delivery into peripheral veins of humans was problematic. To solve the problem Stanley Dudrick adopted a technique described by Aubaniac, a French army surgeon, in which the subclavian vein was punctured percutaneously to gain access to the large central veins where high blood flow generally prevented clotting. Thus, he succeeded in infusing highly concentrated solutions of glucose and large amounts of protein without causing venous thrombosis.¹⁴ Douglas Wilmore and Dudrick successfully treated an infant with atresia of the jejunum, ileum, and distal colon soon after this. Nourished entirely by vein, this baby not only gained weight but grew normally.¹⁵

As a result of these landmark reports, intravenous hyperalimentation was rapidly accepted and employed around the world. It has since saved the lives of countless patients who were temporarily or permanently unable to eat. The success of this classic experiment in 1966 was the culmination of Dr. Rhoads' lifetime scientific obsession with perioperative nutrition. Forty-two years later at Dr. Rhoads' 80th birthday celebration, Francis Moore ranked it with the most important scientific contributions ever made by a surgeon.¹⁶ Moore said "There are several things that have occurred in

science during this century, in which all areas of biology and medicine owe a debt to surgery. There was the pump oxygenator (also a Philadelphia product), allotransplantation of organs (for which Boston might claim some credit), certain aspects of the endocrine treatment of cancer (the Nobel [Charles Huggins] is with us tonight), vascular anastomosis and use of lasers to repair the retina and the localization of functional areas in the cerebral cortex. To these epoch-making advances, the kind for which Nobel Prizes are awarded we must add total intravenous feeding, the product of Jonathan's long and tenacious study."

Despite Jonathan Rhoads' preeminence as a clinician and as a surgical scientist his contribution as a mentor of young surgeons may have been even more important. During his 12 years as department chairman his residency program graduated 62 surgeons who have served as faculty members in 34 different medical schools, 28 as full professors and 11 as departmental chairman.

As a statesman of science and medicine, Dr. Rhoads was well known for his record of service to the National Research Council, the Public Health Service, the Congress and the Veterans Administration, and as a consultant to several United States Presidents. His most important influence on behalf of federal support of cancer research came from membership on the panel of consultants on the conquest of cancer, whose recommendations led to the National Cancer Act of 1971.

The esteem with which his colleagues regarded Dr. Rhoads and the service he provided to some 65 professional organizations was evidenced by the number of officerships he held. To mention only a few, those of which he was president or chairman included: The American College of Surgeons, American Cancer Society, American Philosophical Society, American Surgical Association, College of Physicians of Philadelphia, Council of Medical Specialty Societies, International Federation of Surgical Colleges, International Surgical Group, Philadelphia Academy of Surgery, Philadelphia County Medical Society, Society of Clinical Surgery, Society of Surgery of the Alimentary Tract, Surgical Infection Society, and the Society of Surgical Chairmen. In addition, many special awards came to him: The Distinguished Service Award of the American Cancer Society, the Strittmatter Award of the Philadelphia County Medical Society, the Joseph Goldberger Award of the American Medical Society for Clinical Nutrition (with Stanley Dudrick), the Citation of the Association for Academic Surgery, the Roswell Park Medal for Eminent Service to Profession and Humanity, the American Cancer Society National Award, the Distinguished Service Award of the Pennsylvania Medical Society, the Papanicolaou Award, the Medallion for Scientific Achievement and the Flance-Karl Award of the American Surgical Association, the Distinguished Service Award of the American Trauma Society, the *Prix de la Societe Internationale de Chirurgie*, an Honorary Benjamin Franklin Fellowship of the Royal Society of Arts, the American Medical Association's Sheen Award for

Scientific Accomplishment, the Franklin Medal of the American Philosophical Society, the Medallion of the Surgeon General, and the Cosmos Club Award. Several annual lectureships were named for him by organizations, including the Philadelphia Academy of Surgery, the American Philosophical Society, the Department of Surgery of the University of Pennsylvania, and the College of Physicians of Philadelphia.

Surgical colleges of other nations that honored Dr. Rhoads with memberships included those in England, Edinburgh, Canada, Poland, South Africa, Holland, Germany, India, and Ireland. He held honorary degrees from the University of Pennsylvania, Haverford, Swarthmore, Medical College of Pennsylvania, Thomas Jefferson, Hahnemann, Georgetown, Medical College of Ohio at Toledo, Duke, and Yale.

As versatile as Rhoads' was in surgery, his breadth exceeded the scope of the medical profession, to an extent rarely if ever paralleled by a surgeon. In addition to his service as Provost of the University of Pennsylvania, he served on the Board of Public Education of the City of Philadelphia and was on the Trustee or Executive Committees of Bryn Mawr College, the Westtown School, and Haverford College, chairing the latter. He served on the Council of the American Academy of Arts and Sciences, and from 1976-1984, was President of the American Philosophical Society, the oldest and most exclusive of the Country's learned societies, founded by Benjamin Franklin in 1743.

As remarkable as his earlier accomplishments were, in some respects Dr. Rhoads was just getting started when he finished as chairman at age 65. He squeezed another full career into the remaining three decades of his life, thereby becoming progressively more admired for his continuing vitality and achieving a virtually legendary status. Although he stopped operating when he turned 80, the day before this he was fully capable of performing the Whipple procedure on his list. In other respects his activities never decreased. Until the time of his death he remained the most dedicated attendee of conferences, not only of local but also national and international societies. At all of these he participated actively in discussion. He never accepted emeritus status at the University of Pennsylvania (mandatory for all others at age 70). He continued to edit the journal *Cancer* until 1991. Much of his time thereafter was taken by his duties as a trustee in the General Motors Cancer Research Foundation and as Chairman of its Awards Assembly. One reason he enjoyed this position was the value he placed on the opportunity General Motors provided him to use new models of their automobiles. It was no surprise when only a few years ago he selected a Corvette, as he always fancied fast cars and seemed to drive them with reckless abandon. He acknowledged that over his lifetime this proclivity had led to six collisions, none leading to serious injury.

In 1987, Dr. Rhoads' marriage of 51 years ended with Terry's sudden death from heart failure. In 1990, he married

Kathryn Evans Goddard. Kitty, like Terry, is a pediatrician and is the widow of David Goddard, who succeeded Rhoads as Provost of the University of Pennsylvania. This provoked the comment by one wag that he only married pediatricians and she only provosts. Kitty is Jonathan's distant cousin but as he said with a twinkle in his eye, they were not concerned over consanguinity. As he and Kitty traveled all over the world, usually for him to preside or speak at scientific meetings, he seemed as youthful and vigorous as ever.

A few of the personal qualities for which Dr. Rhoads was widely known during his early professional career and through the period of his chairmanship were wisdom, patience, self-discipline, carefulness, consistency, persistence, and an incredible capacity for work. These are qualities to which everyone aspires and they no doubt helped him to become such a successful academic surgeon and chairman. But the consequence of these serious traits was a rather austere façade during that period of life. As much as his residents and young colleagues admired him, and despite ample evidence of his support of them, he seemed somewhat aloof.

In contrast, during his later decades when he was relieved of the pressures of the chairmanship it became clear that the serious and reserved persona for which he had been known was a well-studied façade behind which there was a quite different person. In fact, some of the qualities attributed to him were probably contrived skills rather than innate personnel characteristics. We know from reading between the lines of obscure sources such as the 1927 Haverford Yearbook that the young Jonathan's exuberance was frequently expressed in his college dormitory by disruptive practical jokes. His athleticism, his spontaneity (even impulsiveness) led him during a summer trip to Europe to jump in and swim the Bosphorus (from Asia to Europe). Later, as he navigated the more treacherous waters of academic and political life, Dr. Rhoads probably found that a steadier style was necessary. During that time mainly his family saw his playful or unpredictable side. Occasionally others were treated to a glimpse of it, when he got behind the wheel of a fast automobile or after a dinner party when he might tell one or several jokes from the vast store his incredible memory allowed him to catalogue. Some of these were of questionable taste. Or on one of those rare occasions in the operating room when, provoked by some unfair and totally unacceptable turn of fate, he would momentarily lose control and hurl an instrument or sponge into the wall or to the floor.

At other times the steadier qualities (or skills) worked best. In recent decades long after the trappings and intrinsic power of chairmanships and presidencies were no longer available to him, it became easier to see how effective his methods were. It was an educational experience to watch him work his magic at a scientific meeting, when many people thought he was asleep, or even more so in a committee or board meeting. He usually waited until others were finished before he spoke. He listened carefully to what was said, carefully acknowledging the merits of opinions which

were at variance with his own. He even offered to compromise on one or two points, albeit usually minor ones. He then patiently and exhaustively summarized the pros and cons of the issue with such clarity that the assembled group not only understood them but also recognized the wisdom of his recommendation. He always won out. He probably chuckled over the effectiveness of this patented method. Its success was so consistent that many who studied under him (and thus studied him) tried to emulate it – but never with the same results.

During the last decades of his life, after the austere façade of earlier times had faded and the charm and humor of his underlying persona came through, he became an entertaining and sought after speaker. Of his 68 visiting professorships, 62 came after he finished his chairmanship.

Those who had the honor of caring for Dr. Rhoads during his final illness had a chance to see several other qualities, bone fide intrinsic characteristics, which probably can't be learned: courage and consideration for others. He was reluctant to acknowledge the inevitability of his defeat by his old enemy, cancer, until every possible treatment was considered. But after he came to terms with this he was determined to delay the outcome until he was ready for it. He was the model of a courageous patient. He had decided that whatever the cost in personal comfort he would continue for as long as possible to be useful to his family, his institutions and his colleagues. He carried on with a virtually full schedule of meetings and correspondence until a few days before his death. Although he was always compliant and considerate of his doctors, they understood who was calling the shots. It was especially fitting that the extension of his life by several months (which he greatly valued) was made possible after he could no longer eat by total intravenous nutrition, a treatment he and his colleagues had devised. It was also appropriate that his last days were spent in the Hospital pavilion, which the University of Pennsylvania had named for him and that he was under the care of a group of physicians, which included members of his department and his own family.

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